UNIQUE DESTRUCTION OF A TULIP TREE BY LIGHTNING

By FRANK P. NORBURY, Cooperative Observer

[Jacksonville, Ill., April, 1927]

In the afternoon, about 4:30 o'clock, April 13, 1927, there occurred a thunderstorm at Jacksonville, Ill., a feature of which was the destruction by lightning of a tulip tree standing on the lawn of Hon. Fred H. Rowe. This tree, approximately 125 feet in height, with a base girth of 12 feet, stood in a group of trees distributed on the lawn and the adjacent Duncan Park. It was beginning to bud. It was wet from the rain and the ground thoroughly saturated by the heavy rains of the preceding three weeks. The bolt shattered the tree, causing what appeared to be an explosion, centered in the middle third of the trunk. The photographs show the lower third standing, rent in strips from above downward. The middle third was torn in shreds and strips, excepting a branch extending on the east side, which was severed and propelled fully 25 feet from the main trunk. Strips from the middle third, some measuring 5 and 10 feet in length, were thrown 100 to 200 feet away from the base. Smaller pieces were found even farther away. It is to be noted that very little débris was to be seen. (This is due to the nature of the wood of the tulip tree.) That the disruption was explosive in kind, like that of a firecracker, is confirmed by the observance of a neighbor who chanced to be looking out of the window at the turbulent storm. She said, "that following the stroke the tree trunk flew asunder." There were flares of light circumscribing the trunk, followed by a cloud of smoke, mingled with what appeared as steam. There was little evidence of combustion, but the smell of smoke extended north to the near residences. One neighbor thought her home had been fired by the lightning, as she smelled the smoke. To confirm the probability of explosive force the middle third was so completely shattered that the upper third when torn off fell and lodged in the shattered remains of the lower third, as shown in the photograph. The extent of disruption suggests explosion, which probably was due to the generation of steam, made possible by the intense heat liberated by the positive charged bolt in its contact with the grounded and negative charged tree. It is probable that the inherent qualities of the tulip tree may have been a factor in the phenomena of this unique disruption. This tree was a beautiful specimen of the species (*Liodendron tulipifera*) to be found in central North America, the characteristics of which are absolutely straight, symmetrical, and tapering trunk, with diverging branches, sweeping upward. Its wood is classed among the light woods and has a compact grain. It is a wood that absorbs moisture readily and, like the poplar and cottonwood, will shrink and warp. In the live state "it is full of sap," as its foliage indicates, being very glossy and bright green. Because of its texture, its ability to absorb moisture, and its symmetrical and tall trunk may be noted the factors which account for the peculiar explosive disruption, as shown in the photographs.

LIGHTNING

N. ERNEST DORSEY

[National Research Council, Washington, June 17, 1927]

The editor of the REVIEW has kindly permitted me to study the original prints of Doctor Norbury's very interesting photographs of the blasted tree that forms the subject of the preceding note. Four views are shown, one of which is reproduced above. They reveal several things that seem worthy of careful attention, especially as it is difficult to reconcile them with the commonly accepted ideas regarding the nature of lightning: (1) The seat of the explosion was evidently situated deep in the trunk, otherwise the trunk would not have been so completely shattered, and it was well below the center of the tree. (2) In none of the photographs is there any indication that bark was significantly stripped from the trunk. No pieces of bark can be distinguished among the débris, and in every photograph an examination with a lens shows that those outer splinters that are suitably situated for observation still are covered with apparently undamaged bark. (3) The long upper portion of the trunk, which is seen leaning against the shattered stump, is only slightly damaged, and that damage is superficial and limited to a narrow strip extending (as shown in another photograph) from the butt to beyond the limits of the photograph. The damaged portion is broadest and apparently deepest at the butt and becomes narrower and more superficial as the top of the photograph is approached. It runs parallel with the trunk from the butt to a point hidden by the shattered stump and then begins to spiral gently around the trunk. It would be interesting to know whether the grain of that portion of the trunk is likewise spiral.

It is difficult to reconcile these facts with the commonly accepted idea that we are here concerned with an ordinary current of electricity passing through the air, to the tree, and through that to the ground, the explosion being due to vapors generated in the tree by the heat produced by the passage of the current. Were this the proper explanation, the greatest density of current, and consequently the greatest heating and the greatest damage, would be where the current passes from the air to the tree. For, when once in the tree, that being a very fair conductor, vastly better than the air, the current would spread and would distribute itself in accordance with the conductivity of the various portions of the trunk; the current density in the new sapwood just under the bark would surely be greater than that in the interior of the trunk. Hence the main damage would be relatively superficial and much bark would be ripped from the tree. But this does not accord with the observations. Furthermore, as the tree and the ground were very wet, and hence were good conductors, the tree would have been struck near the top, and the main seat of damage would have been there instead of more than halfway down. If the narrow strip of damage extending along the upper section of the tree is regarded as evidence that the bolt did actually strike the tree near its top, then it is necessary to answer the question: How is it possible for the bolt to have passed down more than half the length of the trunk, damaging only a narrow, superficial region, and then by means of a deep-seated explosion to have completely blasted a lower, but not lowest, portion of the trunk? It seems impossible. If the stroke came down along this strip, then surely the explosion was not produced directly by the stroke, but arose from some secondary effect. If the bolt raised the tree to a very high positive potential,


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the explosion perhaps resulted from a secondary electronic dart initiated by a stray electron which happened to be near the tree, but this does not seem very probable.

From a close study of a similar case,[1] but one in which the explosion was much less violent, I was led to propose the electronic dart hypothesis,[2] which seems to explain many of the queer facts which have been recorded. This hypothesis is based upon the following well-known facts. (1) There are always some free electrons scattered through the atmosphere. (2) When subjected to an electric field of an intensity that can readily be secured in a laboratory these electrons acquire sufficient energy to enable them to dislodge an electron from each atom with which they collide. In still more intense fields they will acquire in a given time more energy than they expend. In such fields, if maintained, they may attain an exceedingly high velocity. (3) Each electron freed from an atom behaves likewise. Thus a single free electron may give rise to a great swarm of electrons traveling through the field at a high velocity. Under the combined action of the field and of the mutual repulsion of the constituent electrons, such a swarm will become elongated in the direction of motion. This elongated swarm may be described as a dart of electrons. (4) While traveling at a high velocity, the resulting magnetic field confers upon the electrons a great inertia, and gives rise to forces which largely neutralize the mutual electrostatic repulsion of the constituent electrons, thus permitting them to keep together.

On the dart hypothesis, a lightning stroke of the type that produced the damage under study consists of such an electronic dart traveling at a tremendous velocity. When it strikes a tree it penetrates to a certain distance before its forward velocity is arrested. As the forward velocity is reduced, the magnetic field is likewise reduced, the mutual repulsion of the electrons becomes rapidly more effective, and they tend to spread in all directions, up and sidewise as well as down. The electrons become attached to the atoms of the tree, and these greatly impede their progress; hence, the tree is subjected to great strains of electrostatic origin. In the case studied there was a small, definitely bounded column of shredded fibers extending along the grain in both directions from the center of explosion, indicating that the electrons, presumably after becoming loaded with atoms, passed in those directions, but there was no indication that they passed across the grain. It appeared that the resistance to their passage in that direction was so great that in their attempt to pass they rent the tree asunder before they penetrated in sufficient numbers to leave a visible trail of damaged fibers. As the electrons spread their mutual repulsion decreases, and consequently their ability to cause damage does likewise; hence, in passing along the grain from the center of explosion, whether up or down, the extent of the damage decreases. This agrees with the observations.

The higher velocity of a dart the greater is its inertia and the less is its path affected by the presence of conductors or of other charged bodies. It strikes a certain point mainly because that point happens to lie in its path. That the striking of an object by lightning may have nothing to do with the ability of that object to facilitate the passage of the charge to earth is well illustrated by the case of the flagstaff on the old four-story, brick building at 1701 Pennsylvania Avenue, Washington, D. C., which was struck on the afternoon of August 17, 1926. The staff was of wood, old, well seasoned, painted, sound, and very light. A column of shredded fibers about an inch beneath the surface extended along the grain from a point about 9 inches below the top of the staff to a point about 4 feet above the iron collar which surrounded the staff 6 feet above the roof and which was attached to the metal roof by three iron rods, forming a tripod. The top 6 inches of the staff was merely split; below the lower end of the shredded column splinters were split off, but the lower 9 feet of the staff was entirely undamaged. The lowest portion of the damage was 3 feet *above* the supporting collar. There was no evidence that the bolt touched the supporting collar, its tripod, the roof, or a neighboring chimney, perhaps 6 feet distant. A few pieces were simply bitten from the side of the staff and thrown to the street. They were removed before they could be examined. These peculiarities are entirely normal on the dart hypothesis, but seem paradoxical on the theory commonly accepted. In view of the evidently large amount of air which was contained in the pores, it is difficult to see how the vaporization of the small amount of moisture in them could have given rise to sufficient pressure to have caused the damage.

In a recent attempt[3] to prove theoretically that a lightning stroke can not consist in the advance of a negative charge, the characteristics of such electronic darts as we have here postulated were not considered. Hence, in reference to the dart hypothesis, the proof advanced is irrelevant. Furthermore, it seems to be inextricably bound up with the assumption that the electrical field at the tip of an advancing stroke has, at least roughly, a spherical symmetry, the force diverging in all directions from the tip. It is difficult to see how this can be true in any actual case, except possibly at those points at which the advance is checked. The article is so vague that it is impossible to determine on what grounds the author based the assumption.

In the same article the extreme rarity of photographs showing strokes that appear to have branches pointing from the ground is advanced as proof that strokes corresponding to a negatively charged cloud are exceedingly rare. Mere rarity is for our present purposes irrelevant, as we are considering only a particular stroke. But it should be noticed that the proof advanced rests upon the tacit assumption that all strokes correspond to the advance of a positive charge, or that the frequency with which negative strokes, if existent, are branched is essentially the same as that for positive strokes. Neither assumption is necessarily true. On the dart hypothesis there are strokes corresponding to the advance of a negative charge, and the positive strokes should be branched much more frequently than negative ones. On this hypothesis a positive stroke[4] advances by a series of steps depending upon the occurrence of free electrons, each of which participates by giving rise to a dart shooting from without, and somewhat in advance, into the stroke. The electrons run in the direction in which the field increases, a condition favorable to the formation of a powerful dart. Each dart leaves a trail of positively charged atomic residues, and thus extends the positive stroke. The stroke advances by accretions from without, and these may come from the side as well as from the main line of advance, depending upon the distribution of stray free electrons. Branching is to be expected. On the other hand, a negative stroke advances in a mighty rush until the field, the raindrops, or other material encountered by it causes a temporary halt; then it starts

[1] Dorsey, N. E.: MONTHLY WEATHER REVIEW, 53:479–483, 1925; Journ, Washington Acad Sci., 16:87–93, 1926 (some misprints).
[2] Dorsey, N. E.: Journ. Franklin Inst., 201: 485–496, 1926.
[3] Simpson, G. C.: Proc. Roy. Soc. A, 111 : 56–67, 1926; *cf.* Nature, 118 : 190, 481, 1926.
[4] *cf.* Dorsey, N. E.: Nature, 118 : 190, 482, 1926.

off again in another rush. Furthermore, an electron suitably situated for the formation of branch will run away from the bolt into an ever-decreasing field, a condition adverse to the formation of a powerful dart. If branches occur they will probably be very few and weak, except in the neighborhood of a temporary or permanent halt. There the field becomes exceedingly great, and thence branches may radiate in many directions. Star-like branching is observed and has been photographed, but whether it is real or the result of extreme foreshortening, the direction of the main trunk being very straight and coinciding with the line of sight through the center of the star, I am unprepared to say. Such a star may be seen to the left in the photograph published by Doctor Hoffert in 1890.[5]

Types of lightning that can not be satisfactorily explained by an extension of the dart hypothesis probably exist. For example, in multiple strokes those subsequent to the first probably involve much lower field intensities and are more like ordinary discharges through an ionized gas; ball lightning seems certainly to require a quite different explanation. In order to disentangle the various types it is necessary to study in detail actual flashes and their effects. These must be studied individually and be carefully classified. To bunch them and to discuss average effects will get us nowhere. In this study the effects of minor strokes are of great value, as they will probably yield more detailed information than can be obtained from those of the more spectacular ones. The latter are likely to be complicated by secondary effects, and precious evidence may be destroyed by the violence which characterizes them.

[5] Hoffert, H. H.: Ploc. Phys. Soc., 10 : 176–179, 1890; Boys, C. V.: Nature, 118 : 749, 1926.

TORNADO OF JUNE 3, 1927, NEAR TOPEKA, KANS.

By S. D. FLORA, Meteorologist

[Weather Bureau, Topeka, Kans.]

A small tornado struck the southwestern suburbs of Topeka one-half mile southwest of the Country Club, about 4:40 p. m. of June 3 and traveled slightly north of east for a distance of 2½ miles before its last damage was done. The long, pendant cloud was sighted 3 miles east of its origin, but apparently did not reach the ground after traveling so far. The path of destruction, which was well defined, was about 100 feet wide.

No one was injured, and the total property damage was estimated at $400. A house near the point where the storm first struck had its roof badly damaged, and the barn, about 50 feet west of the residence, was wrecked, parts of it apparently being carried entirely over the residence and distributed over a field in the east. Some of the wreckage landed in a tree top just east of the house.

The storm passed over the southern outskirts of Topeka with very little damage, except that just noted, and slight damage to a greenhouse, to a few shade trees, and an occasional outhouse.

The storm followed a light fall of hail and came with a terrific roaring. The characteristic cloud of the tornado was seen by a number of persons.

A curious freak of the violence of the wind was a 2 by 4 pine rafter of a barn that was driven entirely through the siding and 2-inch wall of a near-by house without any battering of the pointed end of the rafter.

TORNADO AT AUBURN, KANS., JUNE 3, 1927

By EDWARD C. CORKILL, Junior Observer

[Weather Bureau, Topeka, Kans.]

The small tornado which struck Auburn, Kans., a small town about 18 miles southwest of Topeka, was seen to form about 1 mile west of Auburn by two clouds, one a black one coming from the north and a nearly white cloud coming from the south. When they met they began to whirl and turn to a dark gray color, making a very loud roar, and move eastward very rapidly.

From this cloud two distinct funnel-shaped clouds were seen to emerge and strike the ground and pick up several small trees and brush that was piled; one of the trees was carried for over a mile before it was dropped. When the tornado hit a timber about one-half mile west of Auburn it uprooted about a half dozen elm trees, varying from 12 to 24 inches in diameter, and one was split in the center for about 12 feet—this due to the twisting motion.

From here the funnel-shaped clouds lifted for a moment, but dipped to the ground again, striking a steel windmill and twisted the wheel around the tower so that it had to be removed for repair. They broke several shade trees and tore shingles from houses on either side of the street, but did not disturb the trees growing close to the street, showing that the two funnel-shaped clouds traveled in very nearly parallel courses about 100 to 150 feet apart.

Each of the funnel-shaped clouds was about 50 to 100 feet in diameter at the lower part and seemed to dip to the ground at about the same time. The third time they struck the north one tore shingles off of the school building and tore an entrance hall to the basement off, blowing it into five sections, and was seen to hurl it into the air about 75 feet before dropping it. Two or three small buildings around the school building were wrecked, also several large maple trees were broken off by the south funnel-shaped cloud.

Thence the path of the funnel-shaped clouds was through an orchard and to a farmyard where the south one completely wrecked a barn, but hurt none of the six head of livestock which were all in the barn. The stall in which one horse was tied was all that was left standing. Most of the roof was hurled into a hedge fence, which was partly uprooted.

The storm was accompanied by a terrific roaring and heavy rain but very little hail. The time of occurrence was about 6:30 p. m., and the tornado clouds lasted for only a few minutes before they united and dissipated about one-half mile east of Auburn. The course was a little north of east. The total damage was estimated at about $1,000. No lives were lost and no one injured. One peculiarity of the tornado was that the two funnel-shaped clouds emerged from the same cloud and struck at about the same time.